# Wind Farm - Project Plan

## IPRO 344 - FALL 2006

**Sponsor:** Michael Polsky, Invenergy LLC

**Team Members:**
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## Objective

The objective of IPRO-344 is the design of a wind turbine. To accomplish this, the following tasks must be completed:

- Selection of an appropriate site, taking into account wind availability, proximity to transmission lines, environmental impact, and the selling price of electricity at the location.
- Mechanical design of the wind turbine, including the blades, turbine, and tower.
- Electrical design of the generator, grid interconnection, and control system.
- A study of the economics of the design, including a life-cycle cost analysis.

## Background

The past few decades have seen tremendous increase in the use of renewable energy resources. With increasing costs and limited availability of fossil fuels, as well as increased concern about environmental issues, much attention has been focused on using renewable, environmentally-friendly energy sources to supply a portion of the nation's energy needs. Wind energy is a reliable, abundant natural resource. It is one of the fastest growing renewable energy technologies, due to its minimal environmental impact and low cost of installation and operation.

Invenergy LLC, the sponsor of IPRO 344, was founded by Michael Polsky in 2001, and he remains the President and CEO. Invenergy specializes in development and acquisition of various power generation systems with an emphasis on renewable resources. With nearly 30 years of experience in the energy industry, he is widely recognized as a pioneer and an industry leader in independent power generation in North America. Prior to forming Invenergy, Polsky founded SkyGen Energy, in 1991, where he led efforts to develop a 12,000 MW portfolio of power generating projects and built one of the most successful development teams in the independent energy industry.

As of today, there is a total wind generation of 10,039 MW in the United States. In Illinois, there are two major wind farms, in Mendota Hills and Pike County, currently producing about 100MW of electricity. As of July 31, 2006, Illinois ranks 16th in the United States for wind development, with a total installed capacity of 107 MW, but an additional 1,541 MW have been proposed through various projects. The McLean Wind Energy Center, for example, proposed by Invenergy, would consist of 100 1.5 MW turbines, for a total installed capacity of 150 MW, which would more than double the current installed capacity in Illinois.

The purpose of a wind turbine is to convert the kinetic energy of wind into electrical energy. When wind blows, a high pressure area is formed on the front surface of the blades, while a low pressure area is formed on the rear surface. The blade is therefore pulled into the low pressure area causing the shaft to rotate, much in the same way that the wing of an airplane provides lift. The rotating shaft is connected through a gearbox to the rotor of the turbine's generator. As the rotor spins, electromagnetic induction produces a voltage at the output of the generator, usually around a few hundred volts. The generator is then connected via heavy electrical cables to a step-up transformer at the base of the turbine's tower to increase the voltage into the range of a standard distribution system, or around several thousand volts.

If the wind farm contains several wind turbines, they are all connected to a central collection point, where the power is combined into one output. This output can then either be fed to a local village, or cabled to a substation, where it is again amplified to transmission-voltage power, or hundreds of thousands of volts. This high voltage allows the electricity to be sent via transmission lines over long distances with lower transmission line losses.

The two major mechanical design aspects that affect the power output of a wind turbine are rotor size and tower height. As the rotor size increases, so too does the power output. Additionally, because wind speeds near ground level are relatively low, due to interference from buildings and other surface-level obstructions, it is desirable to make the tower height sufficiently large to eliminate these effects.

Most wind turbines reach their optimum power generation at a wind speed of 35 mph. Wind speeds above approximately 45 miles per hour require that the turbine initiate a slow-down to prevent damage. This can be accomplished either by controlling the pitch of the rotor blades, or by stall control which produces turbulence behind the blades to slow the wind flow. An active stall control system acts much like a pitch control system, but instead of changing the angle of the blade to minimize the surface area of the rotor that is affected by the wind, the angle is increased, and the wind striking the flatter surface of the blade causes turbulence, slowing the rotor. Finally, a mechanical braking system is essential for when the unit must be shut down due to maintenance or other safety requirements.

Previous wind projects have encountered many problems, primarily consisting of economic, environmental, and technological issues. Environmental issues include visual impact, noise, electromagnetic interference, and impact on birds. Technological problems may include issues related to fault protections and stability, as well as power quality issues.

Utility-scale wind power can typically be installed for a cost of around $1,000 per kW, which is very competitive with traditional generation methods. Additionally, unlike traditional generation technologies, there is no fuel cost. The problems, however, arise due to the unpredictable nature of wind power. Because large traditional generators may take a very long time to start up and shut down, it is necessary to schedule a day in advance which units will be used for the following day, based on the expected electricity demand. Enough units must be turned on in advance to supply the entire load. Because the wind can not be precisely predicted, additional thermal units must be committed in advance, in case the wind prediction is not accurate. Because of the additional cost of running extra generators that may not be needed for more reliable generation technologies, the actual value of wind energy is significantly reduced. This issue has been addressed through energy storage in batteries or other means, so that the net power output is much more predictable.

Although wind turbines are considered to be a very environmentally friendly power generation technology, wind turbines can still have a negative impact on their immediate environment. Wind turbines are almost always large, highly visible structures, and are therefore sometimes opposed by local residents. They also produce a significant amount of noise as the turbine blades rotate. The volume level has been compared to normal background noise, such as traffic, airplanes, and trains, but because wind projects typically are located in quiet, rural areas, noise has been a crucial factor in many projects. Additionally, wind turbines produce a magnetic field that may interfere with nearby electronic devices that are sensitive to such interference.

In any power system, the total energy supplied must equal to total energy consumed. Therefore, if there is a sudden rise or fall in the demand, due to a faulted power transmission line or other disturbance, all generators must quickly adjust their power output to match the change. In the case of wind, unlike traditional generators which are propelled by thermal machines, the input power can not be as directly controlled. Wind power can also cause disturbances in the power system, due to sudden changes in wind patterns. These issues can be addressed through energy storage. By storing energy in batteries or pump storage systems, transient disturbances in the generation can be avoided. Also, due to the power electronics associated with grid interconnection, wind power can result in line power quality issues, especially if the power is rectified and inverted before it is supplied to the grid.

Expected problems related to this specific project primarily include difficulties in gaining access to all of the pertinent information for selection of an optimal site, such as average wind speeds and energy selling price. Additionally, the IPRO group lacks sufficient experience in several crucial areas related to the project, such as in the design of protection systems. With research, it is expected that these difficulties can be overcome.

## Methodology/Brainstorm/Work Breakdown Structure:

The project is divided four stages, and for each stage the tasks are delegated to the team members.

**STAGE 1**

We divided in to 3 groups for stage1:

- Study of energy storage - Several different energy storage technologies will be studied, such as batteries and pump storage (Mike, Azim, Sandhya)
- Location - Approximately three wind sites will be studied in detail, including an analysis of the optimal type of turbine for each site (Bahram, Jieum, Choi, Dan **(Sub-team leader))**
- Turbine - Several different turbines will be studied, including their effectiveness in different wind environments (Sushma, Song, Luke **(Sub-team leader),** Sandhya)

**After Stage1 the group will choose one site and turbine.**

**STAGE 2**

For stage2, three groups were divided based on the major of the students.

- Mechanical Design - (Luke, Song, Dan)
  - Generator Design (Size & Type)
  - Tower Design
  - Foundation
  - Building Codes
  - Blade Size
  - Mechanical Protection
  - Control (Pitch & Orientation)
  - Safety
- Electrical Design (Mike, Azim, Sandhya, Sushma, Bahram)
  - Energy Storage (Mike)
  - Power Electronics and Grid Interconnection (Sushma, Mike, Sandhya)
  - Protection, Control, and Safety (Azim, Bahram)
- Business - (Jieum, Choi)
  - Value of wind energy
  - Market factors

**STAGE 3**

In Stage 3 we again divided into sub-groups for Simulation Studies

- Electrical Simulations in SIMULINK, PSSE (Sandhya, Sushma, Bahram, Dan)
- Structure Simulations (Luke, Song, Mike)
- Market Simulations and Studies (Mike, Azim, Jieun, Choi)

**STAGE 4**

In Stage 4 we will work on Final Report, Poster, Abstract, Presentation, Drawings and Schematics. We divide all this work equally and help each other accordingly.

- Drawing and Schematics
  - VISIO for Electrical System (Sushma, Dan) (week11)
  - Auto CAD for Mechanical System (Song, Azim, Luke) (week11 &12)
  - Site Drawings (Luke, Bahram) (week 11)
- Poster and Abstract: Due Nov 22 (Mike, Jieun)
- Presentation: Due Nov 29 (Choi, Bahram will join Choi in week 12 and Azim in week 13)
- Final Report: Due Nov 30(Sandhya, Dan & Sushma will join Sandhya in week 12 and Song & Luke in week 13)

- MS Project: Sandhya
- Mid-term Report: Mike

## Expected Results

- Mechanical Design and AutoCAD drawings showing the mechanical structure.
- Contour maps of selected location
- Electrical Design and circuit schematics for Generator System which includes Generator, Power-Electronics, Protection
- Analysis of life cycle cost analysis for economics
- Analysis of market impacts
- Environmental impact

## Project Budget

There is no funding available for this project.

## Individual Team Member Assignments (Sub-team leader in bold)

Team Members:

| Name | Major |
|---|---|
| Luke Cho | Mechanical Engineering |
| Euddum Choi | Business |
| Sushma Dantapalli | Electrical Engineering |
| Sandhya Duggirala | Electrical Engineering |
| Bahram Kayvani | Electrical Engineering |
| Azim Lotfjou | Electrical Engineering |
| Sung Song | Mechanical Engineering |
| Dan Taulbee | Electrical Engineering |
| Michael Urbina | Electrical Engineering |
| Jieun Yoo | Political Science |

**Stage 1:**
Energy Storage: **Mike**, Azim, Sandhya
Location: Bahram, Jieum, Choi, **Dan**
Turbine: Sushma, Song, **Luke**, Sandhya

**Stage 2:**
Mechanical Design: **Luke**, Song, Dan
Electrical Design - Energy Storage: **Mike**
Electrical Design - Power Electronics and Grid Interconnection: Sushma, **Mike**, Sandhya
Electrical Design - Protection, Control, and Safety: **Azim**, Bahram
Business: Jieum, Choi

**Stage 3:**
Electrical Simulations: **Sandhya**, Sushma, Bahram, Dan
Structure Simulations: **Luke**, Song, Mike
Market Simulations: **Mike**, Azim, Jieun, Choi

**Stage 4:**
Visio Drawings of Electrical System: Sushma, Dan
AutoCAD drawings of Mechanical System: Song, Azim, Luke
Site Drawings: Luke, Bahram
Poster and Abstract: Mike, Jieun
Presentation: Choi, Bahram, Azim
Final Report: Sandhya, Dan, Sushma, Song, Luke, Mike, Bahram, Azim, Choi, Jieun

## Designation of Roles

Minute taker: Sushma
Agenda Maker: Mike
Time Keeper: Mike
Timesheet Collector/Summarizer: Dan
Master Schedule Maker: Sandhya
Website Administration: Azim